RADAR SATELLITES AND MARITIME DOMAIN AWARENESS

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BACKGROUND

- Ship Detection Performance using Radar
  - RADARSAT-2
  - Constellation of Small-Sats
- Technique for Radar and AIS Satellite Constellations
  - Trials/Operations
  - Performance

REQUIREMENT

- Persistent Surveillance of Oceans
  - All Weather, Day and Night
  - Accurate Geolocation
- Detection, Classification, Tracking, Identification, Intent
- High Probability of Detection
- Low Probability of False Alarm

CONSTRAINTS

- Satellite Radar Sensor
  - Cost
  - Area Coverage Rate
  - Resolution (25 m to 50 m, or better)
  - Performance (PD, PFA)
  - Constellation of Satellites (less than 6)
- AIS, Other Sensors on Board or Available
  - Radar and AIS reports within 10 min of each other

STUDY SENSORS

- RADARSAT-2
  - MSSR, ScanSAR Narrow
- Expanded Beam WiSAR
  - WiSAR (MacDonald Dettwiler and Associates)
- AIS and Other Sensors **Fusion** Assumed
- Focus on Multiple Detections of Each Target
  - Detection, Tracking, AIS Validation

STUDY METHOD

- Express Results/Requirement in Terms of Detections of Ship in Transit Across AOI
- Use AGI's Satellite Tracking Kit (STK 8.2)
  - Industry Standard
  - Object Model for Iterations (new in 2007)
  - Setup Scenario using GUI; Hybrid Approach
  - Drive STK using Scripting (VBS)

TYPICAL STK SCENARIO

- Create Ship
  - Set Waypoints, Speeds, Sailing Time
- Create Satellite(s)
  - Define Sensor Beam
- Create Constellation (if required)
- Choose Report
- Execute STK many Times for Different Sailing Epochs using Script

MSSR

- Considered by Canada's "Polar Epsilon"

Polar Epsilon Requirement	
Probability of False Alarm	$2x10^{-9}$/Res. Cell
Probability of Ship Detection	0.9
Minimum Detectable Ship in Sea State 5	25 m
Principal AOI	1000 nmi off Coast

POSSIBLE MSSR BEAM

Swath Width (50% increase over SCNB)	~ 450 km
Polarization	HV,HH
Resolution (Rule of Thumb: about same size as minimum ship length)	~ 25 m
Near Incidence Range	20º-34º
Far Incidence Range	46º-55º

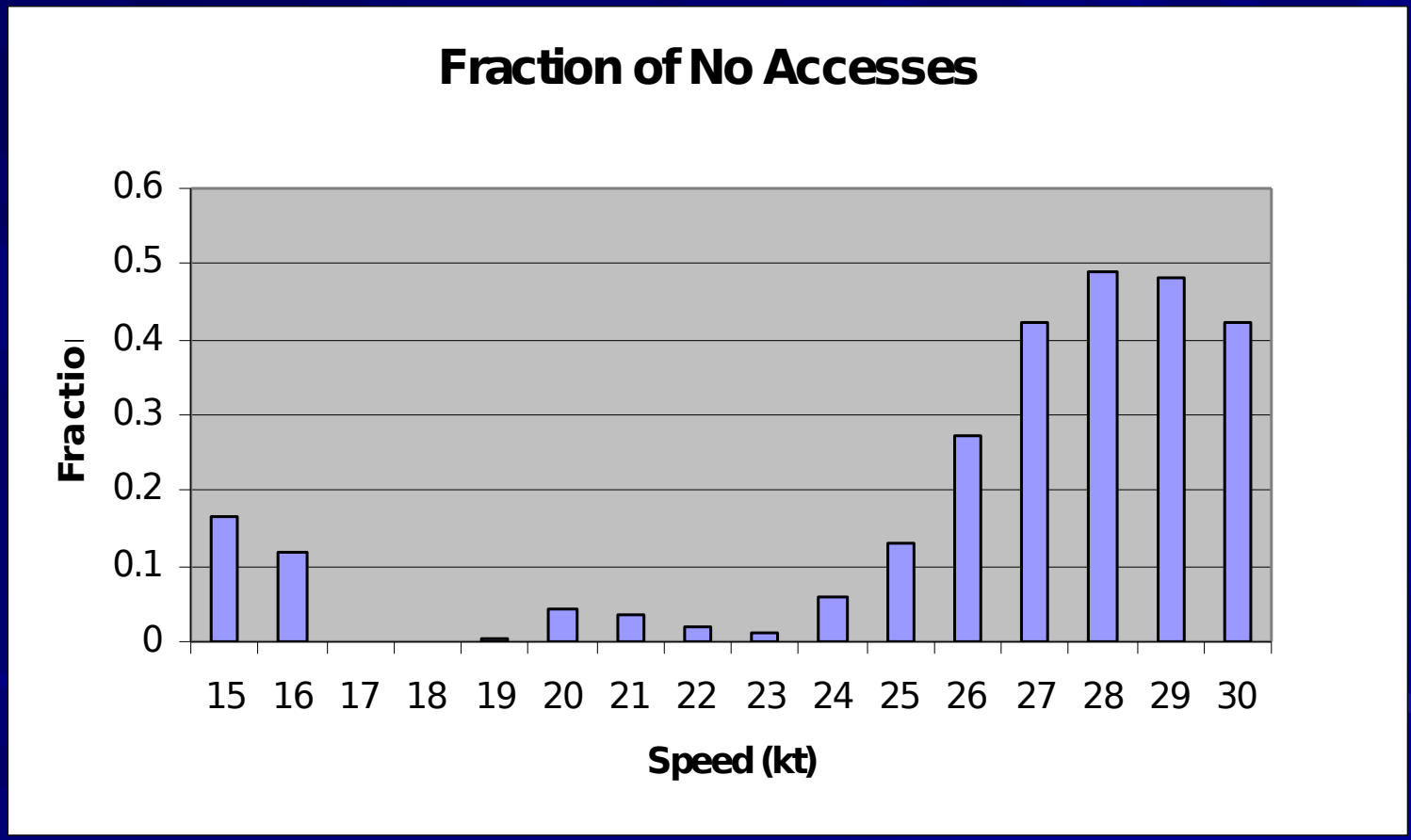
SIMULATION

From	Liverpool/Hong Kong
To	Halifax/Vancouver
Sailing Interval	1 hr
Total Simulation Time	32 days
Speed Range (fixed and random)	15 kts to 30 kts

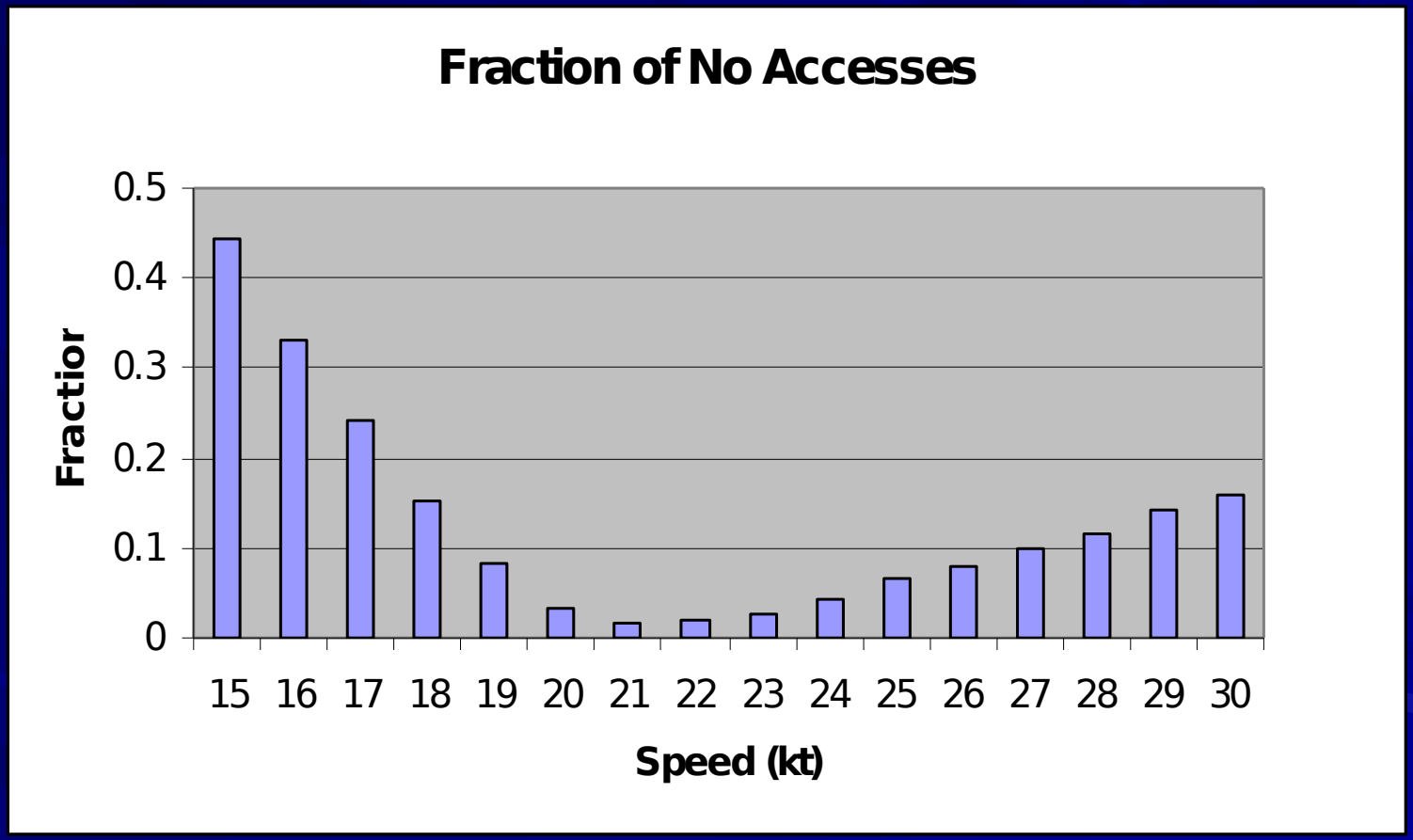
SHIP WAYPOINTS

Description	Latitude	Longitude
Liverpool	53º 24’	-3º 00’
North Anglesey	53º 30’	-4º 30’
Irish Sea	53º 20’	-5º 00’
South Ireland	52º 00’	-6º 00’
Southwest Ireland	51º 00’	-11º 00’
South Newfoundland	46º 00’	-53º 30’
Halifax	44º 38’	-63º 35’

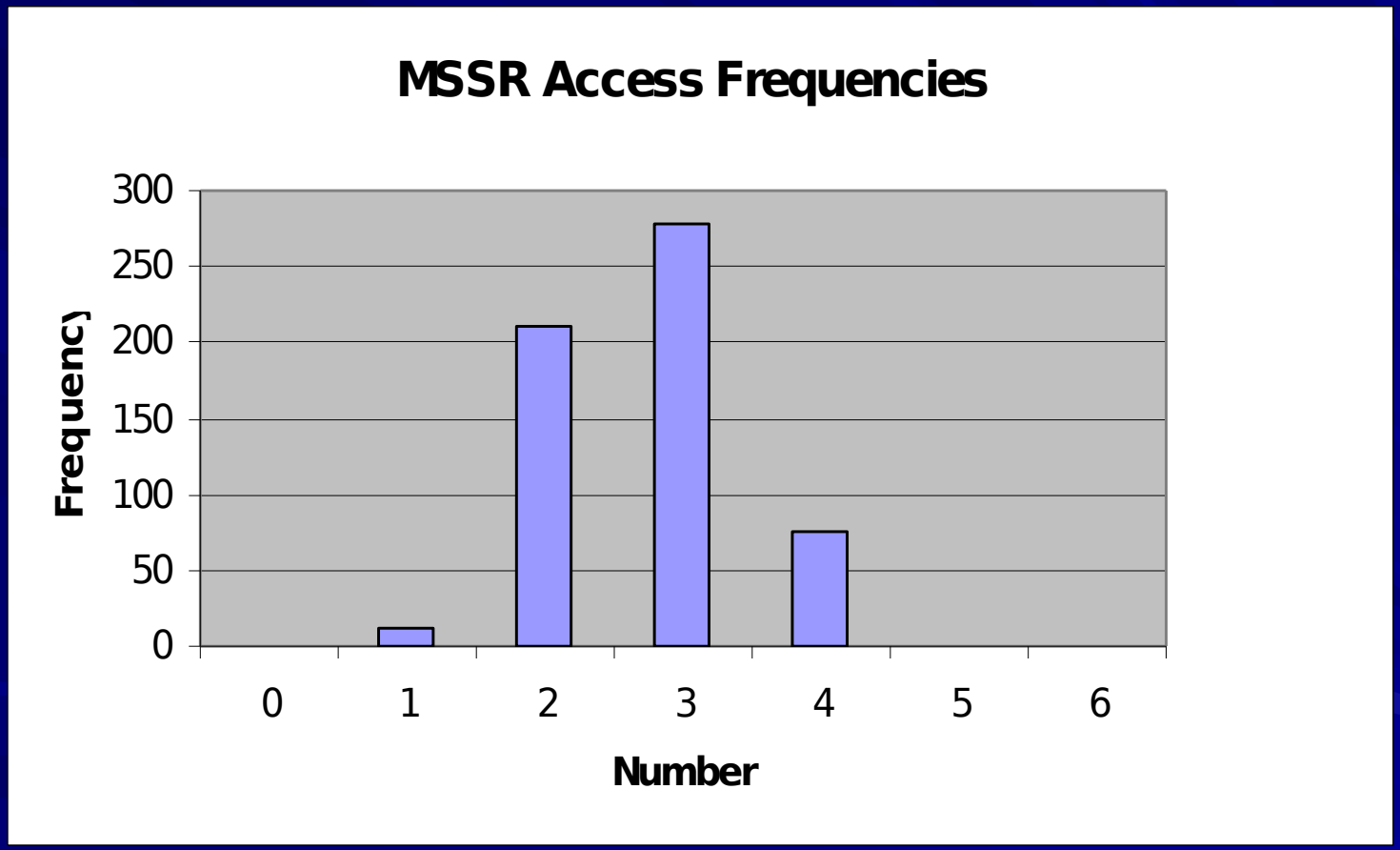
SCNB LIVERPOOL-HALIFAX



SCNB HALIFAX-LIVERPOOL



MSSR ACCESSES Liverpool-Halifax at 20 kts



PROBABILITY

- Probability of Exactly n Accesses = p_n
- Probability of Detection on One Access = p_D
- Probability of No Detection on Multiple Accesses:

$$P_0 = \Sigma_n \, p_n (1-p_D)^n$$

where $p_D = 0.9$

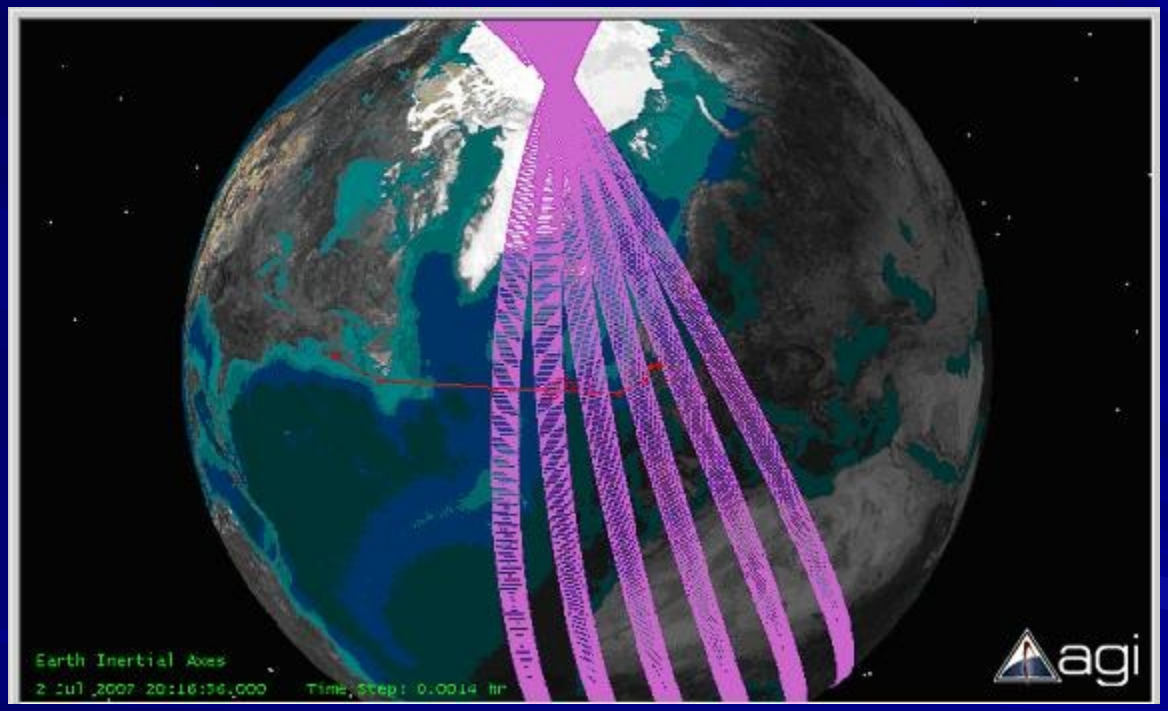
MSSR & SCNB DETECTION PROBABILITIES (RANDOM SPEEDS 15 to 30 kts)

Voyage and Beam	**Probability No Detection**
Liverpool to Halifax – SCNB	0.19
Halifax to Liverpool – SCNB	0.15
Liverpool to Halifax – MSSR	0.11
Halifax to Liverpool – MSSR	0.06
Hong Kong to Vancouver – SCNB	0.015
Hong Kong to Vancouver – MSSR	0.0003
Atlantic 1000 nmi AOI to Halifax – SCNB	0.41
Atlantic 1000 nmi AOI to Halifax – MSSR	0.25
Pacific 1000 nmi AOI to Vancouver – MSSR	0.41

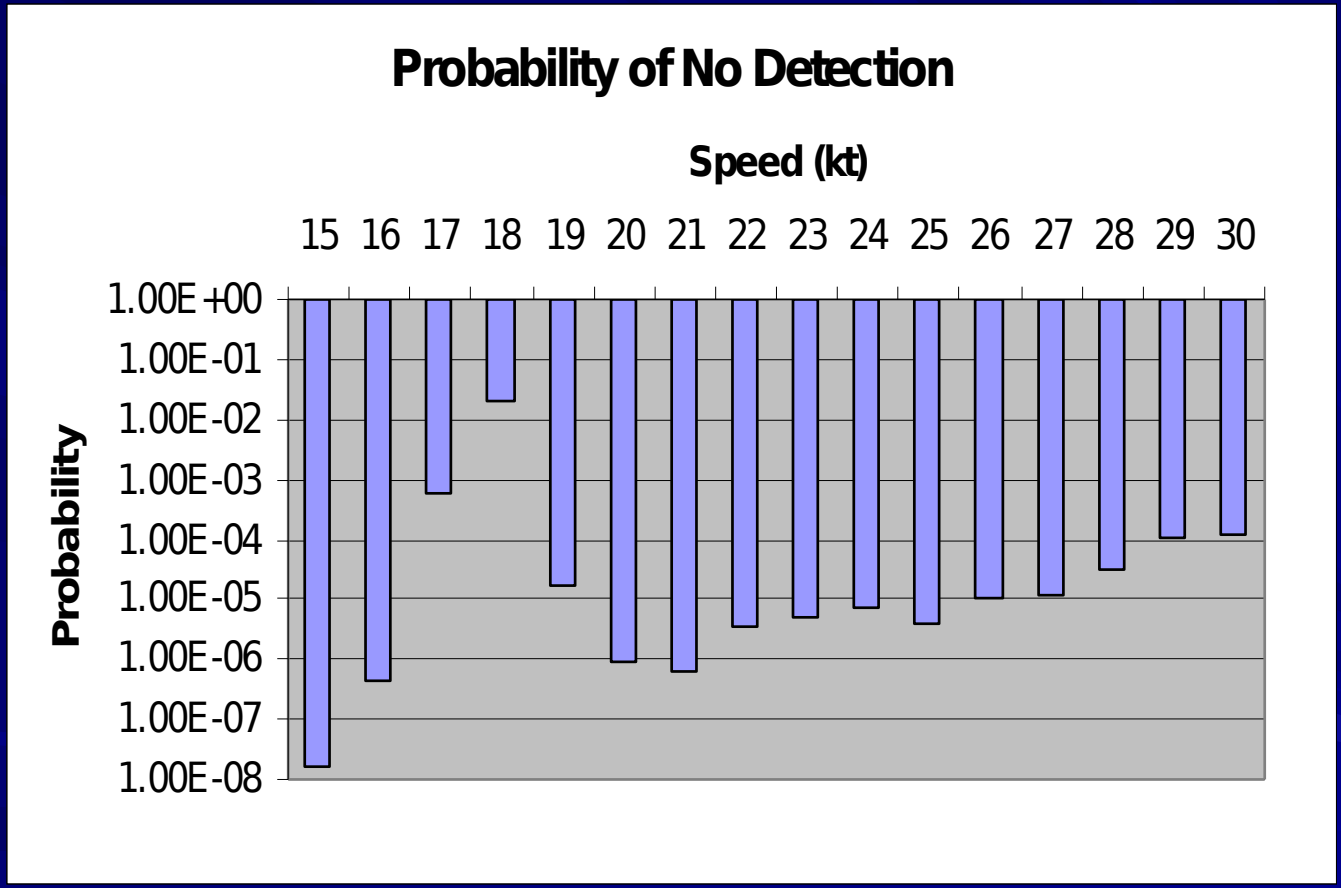
WiSAR PROTOTYPE ORBIT SWATH 350 KM

Parameter	**Value**
Altitude	600 km
Type	Sun-synchronous, circular.
Local Time of Ascending Node	06:00
Mean Motion	14.8934 revolutions/day
Repeat Cycle	Unknown

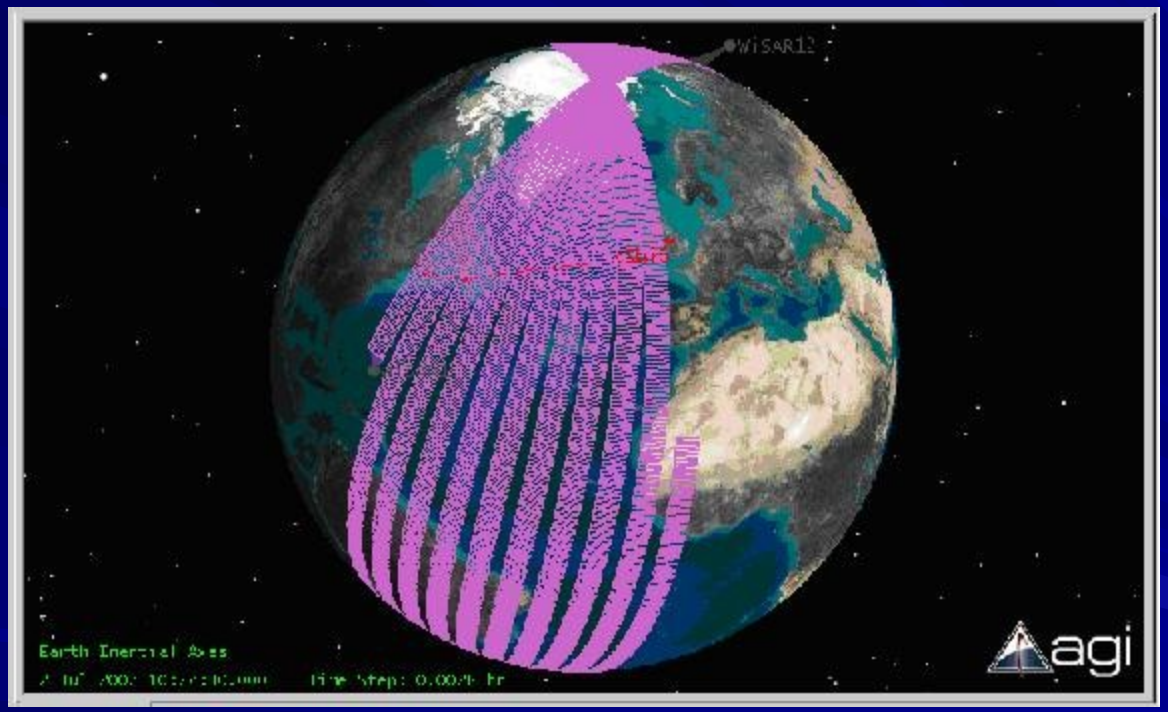
SWATHS FROM 3 WiSARs



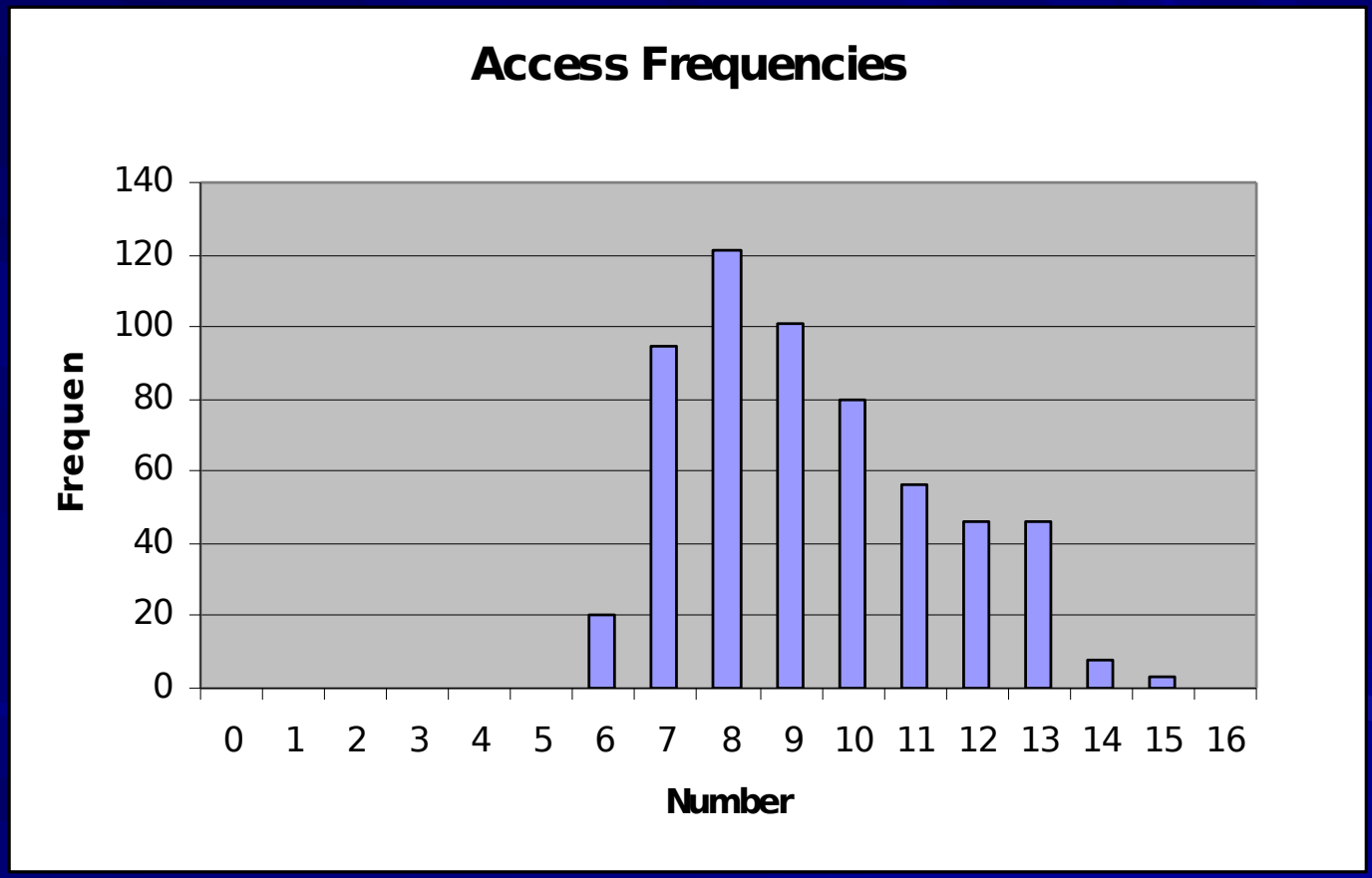
3-WiSAR PROBABILITIES LIVERPOOL-HALIFAX



4-WiSARs, 1-PLANE SWATH 410 KM



4-WiSAR ACCESSES LIVERPOOL-HALIFAX



4-WiSAR RESULTS

Voyage	**Probability of No Detection**
Liverpool to Halifax (Random Speeds)	$<10^{-6}$
Atlantic 1000 nmi AOI	<0.01

MSSR CONCLUSIONS

- The MSSR swath width provides a much better detection performance than SCNB
- For Atlantic and Pacific crossings MSSR provides a significant MDA capability (if combined with AIS)
- For 1000 nmi AOIs, the performance will be useful but does not satisfy a realistic requirement

WiSAR CONCLUSIONS EXTENDED SWATH (410 KM)

- A constellation of 3-WiSARs in one plane provides good but incomplete MDA for ocean crossings and for 1000 nmi Canadian AOIs (but certainly not for north-south voyages)
- A constellation of 3-WiSARs in 3 planes has poor performance
- A constellation of 4-WiSARs in one plane satisfies the radar component of the Canadian requirements and probably most of the US requirement as well

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AIS CONCLUSIONS

- STK technique for determining imaging opportunities between RADARSAT-2 and ORBCOMM satellites is fast and inexpensive (STK Scenario + Script)
- STK technique is appropriate to performance estimation using N radar satellites and M AIS satellites with various constraints